“Sorbent Injection for Small ESP Mercury Control in Low Sulfur Eastern Bituminous Coal Flue Gas”

Project Number : DE-FC26-03NT41987

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September 12, 2003

STATEMENT OF PROJECT OBJECTIVES

A. Objectives

URS Group and their test team will evaluate sorbent injection for mercury control on sites with low-SCA ESPs, burning low sulfur Eastern bituminous coals. Full-scale tests will be performed at Plant Yates Units 1 and 2 to evaluate sorbent injection performance across a cold-side ESP/wet FGD and a cold-side ESP with a dual NH_3/SO_3 flue gas conditioning system, respectively. Short-term parametric tests on Units 1 and 2 will provide data on the effect of sorbent injection rate on mercury removal and ash/FGD byproduct composition. Tests on Unit 2 will also evaluate the effect of dual-flue gas conditioning on sorbent injection performance.

Results from a one-month injection test on Unit 1 will provide insight to the long-term performance and variability of this process as well as any effects on plant operations. The goals of the long-term testing are to obtain sufficient operational data on removal efficiency over time, effects on the ESP and balance of plant equipment, and on injection equipment operation to prove process viability.

This sorbent injection technology is targeted as the primary mercury control process on plants burning low/medium sulfur bituminous coals equipped with ESP and ESP/FGD systems. Approximately 38,000 MW of generating capacity exist for bituminous coal-fired power plants with high-efficiency particulate control devices followed by wet lime/limestone FGD. In addition, about 70% of the ESPs used in the utility industry have SCAs less than 300 ft^2/1000 acfm. Therefore, the data from this sorbent injection project will be applicable to a large portion of the market.

One of the purposes of the sorbent injection program is to generate data to show the economic benefits of sorbent injection in a bituminous coal environment with an ESP or ESP/FGD configuration. The program is aimed at using low-cost sorbents. Data from this program will be used to perform an economic analysis of the costs associated with full-scale implementation of a sorbent-based injection system for these types of facilities.

B. Scope of Work

This project will test full-scale sorbent injection at two sites firing low sulfur Eastern bituminous coal. The sorbent injection equipment will be installed upstream of the ESPs at Unit 1 and Unit 2 at Georgia Power's Plant Yates. Two weeks of parametric tests will be conducted at Unit 1 with two different sorbents. The sorbent injection rate will be varied for Norit FGD carbon and one additional sorbent in attempt to achieve mercury removal rates between 40 and 90%. The second sorbent will be chosen before the test program based on performance of sorbents being tested in other on-going sorbent injection programs.

Immediately after Unit 1 testing is completed, two weeks of parametric tests will be conducted on Unit 2 to determine the effect of dual flue gas conditioning on sorbent injection performance. Here, one sorbent will be chosen, based on results of the Unit 1 tests, and evaluated at two different feed rates. The tests will be performed with the fly ash conditioning system either on or off.

The resulting data from the Plant Yates parametric tests can then be used in extrapolating costs for a range of facilities requiring varying removal rates. A one-month test will then be carried out on Unit 1 with either the Norit FGD or alternate sorbent. The selection of the sorbent will be based on the results of the parametric tests. Mercury removal and ash/FGD byproduct composition will be monitored throughout the long-term

test in order to determine the effects on plant performance. The objectives of this program will be accomplished with six tasks throughout the program's period including: project planning; site 1 field testing; site 2 field testing; data and economic analysis; waste characterization; and management and reporting. The expected duration of the program is 24 months.

C. Tasks to be Performed

Task 1 Project Planning. Project planning will include development of a test plan and QA/QC plan, project kickoff meetings, and finalizing host site and cost sharing agreements.

Subtask 1.1 Test Plan and QA/QC Plan Development. Following the project award, a project plan will be developed specifying all tasks to be carried out during the program. The test plan will include information on the two sites to be tested, exact test locations at the sites, planned test conditions, sampling and analytical test methods, responsibilities of each subcontractor and co-funder, and the project schedule. The DOE Contracting Officer's Representative (COR) will be included in discussions with the project team during the planning process to ensure that the project objectives are clearly defined and that the test plan will allow the project to meet these objectives. All team members and the host utility will review the plan before being submitted to the NETL Contracting Officer's Representative (COR) for final review and comment. Work will begin after final acceptance by the COR. Included in the test plan will be a procedure for demobilization and disposal of all test equipment and expendable material following completion of the project.

A QA/QC plan will be developed to ensure the integrity of all data obtained in this program. The QA/QC plan will be reviewed by all team members and by a QA

representative from the prime contractor. Deliverables for this task will include a detailed project plan, a QA/QC plan, and a health and safety plan. Other plans and environmental documents required by the Reporting Checklist in the Cooperative Agreement issued by the Department of Energy will also be prepared under this task.

Subtask 1.2 Project Kickoff Meeting. Following acceptance of the test plan and QA/QC plan, a kickoff meeting will be held to plan and coordinate all project activities. This meeting will be attended by representatives from each participating organization and will include finalization of a program schedule and coordination of all testing equipment and activities. Sorbent selection criteria and existing test data will also be reviewed.

Subtask 1.3 Host Site and Cost Share Agreements. This task will include finalizing the host site agreement (e.g. security clearances, etc.) and all necessary work to finalize the cost share and subcontract agreements between the groups involved in the program.

Task 2 Field Testing at Site 1: Yates Unit 1. Site 1 testing will be conducted at Georgia Power's Plant Yates, Unit 1. Unit 1 burns a bituminous coal in a Combustion Engineering boiler with a capacity of 100 MW. The particulate control is a cold-side electrostatic precipitator followed by a Chiyoda CT-121 wet scrubber for SO_2 control. Task 2 includes activities required for the installation, startup and evaluation of a sorbent injection system for mercury control at Yates Unit 1.

Subtask 2.1 Site Survey and Injection System Development. Initial site-specific activities include gathering preliminary information necessary to develop a detailed draft site test plan and scope of work. Meetings with plant personnel, corporate, and environmental personnel will be held to discuss these tests and the potential impact on

plant equipment and operation. This task includes coordination with the host sites to make necessary arrangements for the installation of test equipment and operation of on-site test programs. Other efforts include finalizing the site-specific scope for each of the team members and finalizing the sorbents to evaluate during the parametric test period.

This task also includes all activities associated with design of the sorbent injection system for Plant Yates. URS plans to subcontract the effort to provide the sorbent injection equipment and labor to operate the equipment to ADA-ES. ADA-ES will coordinate a leasing arrangement with Norit Americas for the injection system, oversee system installation on-site and hire required subcontractors to assist with installation, design and install the distribution manifolds and injection lances for the injection system, operate the equipment during testing and remove the system from the site at the completion of testing. If schedules can be coordinated, the sorbent feeder portion of the injection system may be supplied by ADA-ES from currently available equipment or may be transferred from another DOE test site such as the unit currently being used by ADA-ES during the year-long test of carbon injection at Southern Company's Plant Gaston.

The carbon injection system will consist of a bulk-storage silo and one or two blower/feeder trains. Sorbent is delivered in bulk pneumatic trucks and loaded into the silo, which is equipped with a bin vent bag filter. The sorbent is metered by a variable speed screw feeder into eductors that provide the motive force to carry the sorbent to the injection point. Regenerative blowers provide the conveying air. Flexible hose carries the sorbent from the feeders to distribution manifolds located on the ESP inlet duct, feeding the injection probes. During the site survey visit, engineers will determine the port configurations and possible injection skid locations. This information will be used to

design the injection manifolds and lances. Discussions with plant personnel will identify additional sampling or injection ports, scaffolding, or utilities required at any of the sampling locations or injection locations.

Subtask 2.2 Screening/Parametric Testing. The goal of this task is to measure the effects of sorbent injection at four different addition rates and to determine whether a sorbent other than the benchmark, Norit FGD, will demonstrate improved performance. Shipment and installation of the sorbent injection equipment at Plant Yates is included under this subtask. The injection location will be upstream of the Unit 1 ESP. Three mercury SCEMs will be operated continuously through the parametric tests: one at the ESP inlet, one at the ESP outlet, and one at the FGD outlet. Therefore mercury removal can be calculated across the ESP and across the wet scrubber. It is possible that injection of activated carbon sorbents will enhance the oxidation of vapor-phase mercury and increase the fraction of mercury removed across the wet scrubber. The analyzer at the ESP inlet will pull gas from upstream and downstream of the injection location. These data can be used to compare measured mercury removal to time-of-flight modeling.

Table 1 lists planned short-term parametric tests for Unit 1 during sorbent injection at the ESP inlet. A series of 8-hour tests will evaluate the effect of addition rate on mercury removal for each sorbent. Baseline tests with no sorbent injection will be carried out before and after tests with each sorbent type. Table 2 summarizes the sample types and frequency of collection for the short-term parametric tests. Ontario Hydro flue gas measurements will be conducted once during the baseline condition.

Subtask 2.3 Longer-Term Testing. The goal of this task is to obtain sufficient operational data on removal efficiency over time, effects on the ESP and balance of plant

equipment, and on injection equipment operation to prove process viability and determine the economics. Long-term testing will be conducted for a single sorbent at the "optimum" settings as defined in the parametric tests and approved by both DOE and the host utility. Two months have been allotted in the project schedule between the short-term parametric tests and the long-term test to allow sufficient time to obtain the necessary amount of sorbent material from the vendor. The injection location for these tests will be upstream of the ESP and sorbent injection at the optimum rate will continue for approximately four-weeks. A baseline test period of approximately 3 days will be established prior to the start of the long-term sorbent injection test.

Table 1. Unit 1 Sorbent Injection Test Matrix

Test	Sorbent	Injection	Schedule
	Setup on Unit 1		Days 1-3
BL1	Baseline	0	Days 4-5
AC11	Norit FGD AC	5	Day 6 (8 hours)
AC12	Norit FGD AC	10	Day 7 (8 hours)
AC13	Norit FGD AC	15	Day 8 (8 hours)
AC14	Norit FGD AC	20	Day 9 (8 hours)
AC15	Norit FGD AC	Contingency	Day 10 (8 hours)
BL2	Baseline	0	Day 11-12 (8 hours)
AC21	TBD	5	Day 13 (8 hours)
AC22	TBD	10	Day 14 (8 hours)
AC23	TBD	15	Day 15 (8 hours)
AC24	TBD	20	Day 16 (8 hours)
AC25	TBD	Contingency	Day 17 (8 hours)
BL3	Baseline	0	Day 18 (8 hours)

TBD = To be determined.

Table 2. Sample Collection and Analyses for Unit 1 Short Term Parametric Tests

Location	Sample Method	Parameter(s)	Frequency Per Test Condition
ESP Inlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One Set, BL1 only
	M26A	HCl/Cl_2	One Set, BL1 only
ESP Outlet	SCEM	Speciated Hg	Continuous

	Ontario Hydro	Speciated Hg	One Set, BL1 only
	M17	Loading	Once
	M26A	HCl/Cl_2	One Set, BL1 only
FGD Outlet	SCEM	Speciated Hg	Continuous
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV	Once
ESP Fly Ash	Grab Composite	Hg, Carbon, LOI	Once
FGD Gypsum	Grab Composite	Hg, Carbon	Once
Limestone	Grab Composite	Hg	One Set, BL1 only
Makeup Water	Grab Composite	Hg	One Set, BL1 only

Table 3 provides a summary of the samples to be collected during the long-term baseline and sorbent injection test periods. Ontario Hydro measurements will be conducted at the inlet and outlet of the pollution control device at the beginning and end of the long-term test. Two mercury SCEMs will be operated continuously throughout the test period; one at the ESP inlet, and one at the FGD inlet or FGD outlet, depending upon parametric test results. Additional Method 26A and PSD impactor samples will be collected as noted in Table 7.

Subtask 2.4 Data Collection and Analysis. Data collection and analysis for this program is designed to measure the effect of sorbent injection on mercury control and the impact on the existing pollution control equipment. The mercury levels and plant operation will be characterized without sorbent injection, during short-term parametric testing and during a longer-term evaluation to identify other effects that may not be apparent during short-term tests.

Prior to installing the mercury analyzer extraction probes, a full temperature and velocity traverse will be conducted at the inlet and outlet of the particulate collectors during full-load conditions to determine profiles for appropriate sampling and sorbent

distribution. Extraction locations for the mercury analyzers will be at the inlet and outlet of the ESPs at a location identified from the traverse to indicate the duct average temperature and flow. An additional extraction location will be located upstream of the Unit 1 ESP and downstream of sorbent injection to provide information on the in-flight mercury removal.

Fixed-bed evaluations using activated carbon by URS and others indicate that activated carbon effectively oxidizes mercury once it has reached its adsorption capacity for mercury. It is likely that injection of activated carbon into an ESP will result in both mercury removal and some oxidation of elemental mercury not removed in the ESP. It is uncertain the extent to which this form of oxidized mercury will be removed by a wet scrubber. Tests at Yates Unit 1 will provide an opportunity to evaluate both the oxidation potential of injected powdered activated carbon and the ability of a wet scrubber to remove this oxidized fraction, thus improving the overall removal of the system.

Table 3. Sample Collection and Analyses for Unit 1 Long-Term Tests

Location	Sample Method	Parameter(s)	Frequency [a]	
			Baseline	**Injection**
ESP Inlet	SCEM	Speciated Hg	Continuous	Continuous
	Ontario Hydro	Speciated Hg	--	2 sets of three
	M26A	HCl/Cl_2	--	Once
ESP Outlet	PSD Impactor	Particle Size, Hg		Twice
ESP Outlet or FGD Outlet	SCEM	Speciated Hg	Continuous	Continuous
	Ontario Hydro	Speciated Hg	--	2 sets of three
	M26A	HCl/Cl_2	--	Once
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV	Once	2/week
ESP Fly Ash	Grab Composite	Hg, Carbon, LOI	Once	2/week
	Grab Composite (waste char.)	Waste Characterization	3 five gal. buckets	3 five gal. buckets
FGD Gypsum	Grab Composite	Hg, Carbon	Once	2/week
	Grab Composite	Waste Characterization	3 five gal. buckets	3 five gal. buckets[b]
FGD Liquid	Grab Composite	Hg	Once	2/week
	Grab Composite (separate 5 gal sample)	Waste Characterization	3 five gal. buckets	3 five gal. buckets[b]
Limestone	Grab Composite	Hg	--	Three samples
Makeup Water	Grab Composite	Hg	--	Three samples

[a] Frequency during the baseline and 4-week long-term test periods.
[b] Actual amount of sample obtained may change depending on NETL requirements

Process data typically archived by the plant will be monitored to determine if any correlation exists between changes in mercury concentration with measured plant operation. A correlation is not unusual between temperature and load. Process data collected by the plant and by the project team for Units 1 and 2 are summarized in Table 4.

Table 4. Process Data to be Collected at Plant Yates

Parameter	Sample/Signal/Test	Parametric		Long-Term	
		Baseline	Sorbent Injection	Baseline	Sorbent Injection
Coal	Batch sample	Yes	Yes	Yes	Yes
Coal	Plant signals: burn rate (lb/hr) quality (lb/MMBTU, % ash)	Yes	Yes	Yes	Yes
Fly ash	Batch sample	Yes	Yes	Yes	Yes
Unit operation	Plant Signals: Boiler load Measure of flow for partial unit test (i.e. fan amps)	Yes	Yes	Yes	Yes
Temperature	Plant signal at ESP inlet and outlet	Yes	Yes	Yes	Yes
Temperature	Full traverse, inlet & outlet	Yes	No	No	No
Duct Gas Velocity	Full traverse, inlet & outlet	Yes	No	No	No
Mercury (total and elemental)	Inlet & outlet draft Ontario Hydro Au-CVAAS	Yes	Yes	Yes	Yes
Mercury (total and elemental)	SCEM, inlet and outlet locations	Yes	Yes	Yes	Yes
Sorbent Injection Rate	Feeder, lbs/min	No	Yes	No	Yes
CEM data (NO_x, SO_2)	Plant data – stack	Yes	Yes	Yes	Yes
HCl	EPA Method 26A	Yes	No	No	Yes
Stack Opacity[a]	Plant data	Yes	Yes	Yes	Yes
Pollution control equipment operation	Plant data (ESP power, etc.)	Yes	Yes	Yes	Yes

[a] Opacity is measured at the Unit 1 stack; Unit 2 does not have exclusive opacity measurements (opacity in monitored in the combined Unit 2&3 stack)

URS engineers will coordinate with plant personnel to retrieve the necessary historical plant operating data files. These data will be integrated with the mercury

control data. Engineers will develop a Chain-of-Custody and coordinate with plant personnel to assure coal, fly ash, and FGD solid/liquid samples are collected and tracked properly.

Subtask 2.5 Site Report and Presentation. A site report will be prepared documenting measurements, test procedures, analyses, and results obtained in Task 2. This report is intended to be a stand-alone document providing a comprehensive review of the testing that was conducted at the host utility.

Task 3. Field Testing at Site 2: Yates Unit 2. Site 2 testing will be conducted across the ESP at Yates Unit 2 immediately after the parametric tests on Unit 1. The subtasks identified for Task 3 are identical to those associated with the parametric testing in Task 2 for Unit 1, except that all sorbent injection tests will be conducted upstream of the plant's ESP with the dual flue gas conditioning system turned on and off. There will be no long-term testing on Unit 2.

Unit 2 burns the same Eastern bituminous coal in a tangentially fired boiler with a nameplate capacity of 100 MW. The particulate control is a cold-side electrostatic precipitator equipped with a dual NH_3/SO_3 flue gas conditioning system. Unit 2 has no SO_2 control system. Because Yates Units 1 and 2 are adjacent units, the incremental costs associated with parametric testing on Unit 2 in conjunction with Unit 1 tests is minimal and provides an opportunity to obtain information not otherwise available.

Previous EPRI testing at a plant firing PRB/bituminous blend showed that dual flue gas conditioning could have a significant impact on ACI mercury removal. Flue gas conditioning appeared to inhibit mercury removal across the residence time chamber. In the absence of sorbent, 35 to 45% mercury removal was measured across the residence

time chamber when testing on the non-flue-gas-conditioned duct while 0% mercury removal was measured on the conditioned duct. With sorbent injection, the mercury removal was similar for both cases.

Thus, it would be important to assess the impact of SO_3 and ammonia on ACI mercury control. The DOE/EIA-767 survey indicates that 245 individual units are equipped with flue gas conditioned cold-side ESPs.

Table 5 lists the planned short-term parametric tests for Unit 2. A series of 8-hour tests will be conducted with the flue gas conditioning system on and off for the same sorbent material used in the long-term tests for Unit 1. This will allow comparison of results for Unit 1 and Unit 2 to examine the effects of flue gas conditioning on sorbent performance. Baseline tests will be carried out before and after the sorbent injection test periods. The sample collection and analysis matrix for Unit 2 is shown in Table 6. Ontario Hydro will be conducted once during baseline.

Task 4 Economic Analysis. The data gathered from the field testing at sites 1 and 2 will yield the information needed to refine cost estimates for full-scale implementation of sorbent injection for mercury control. The costs will be based upon plant-specific design criteria including plant arrangement and retrofit issues. Meetings will be scheduled with plant engineers to discuss specific plant issues that may affect control costs.

Table 5. Unit 2 ESP Inlet Sorbent Injection Test Matrix

Test Condition	Sorbent	Injection Rate (lb/Macf)	Flue Gas Conditioning	Schedule
	Setup on Unit 1			Days 1-3
BL1	Baseline	0	On	Day 4 (8 hours)
BL2	Baseline	0	Off	Day 5 (8 hours)
AC11	TBD	A (TBD)	On	Day 6 (8 hours)
AC12	TBD	A (TBD)	Off	Day 7 (8 hours)
AC13	TBD	B (TBD)	On	Day 8 (8 hours)
AC14	TBD	B (TBD)	Off	Day 9 (8 hours)
BL3	Baseline	0		Day 10 (8 hours)

TBD = To be determined. Injection rate A will be the same optimum rate used for the long-term tests on Unit 1. Injection rate B will be selected based on test parametric data for Unit 1.

Table 6. Sample Collection and Analyses for Unit 2 Short Term Parametric Tests

Location	Sample Method	Parameter(s)	Frequency Per Test Condition
ESP Inlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One Set, BL1 Only
ESP Outlet	SCEM	Speciated Hg	Continuous
	Ontario Hydro	Speciated Hg	One Set, BL1 Only
Coal	Grab Composite	Hg, Cl, Ult/Prox, HHV	Once
ESP Fly Ash	Grab Composite	Hg, Carbon, LOI	Once

Task 5 Byproduct Evaluations. Process byproducts will be collected during the test program for determinations of mercury content and stability. Mercury analyses will be performed by URS in order to perform mercury material balance calculations. Samples of ESP fly ash from Units 1 and 2, and FGD scrubber solids and liquid, limestone, and makeup water from Unit 1 will be collected. Additional samples will be collected and sent to an outside contractor, as directed by NETL, for additional waste characterization testing. Specifically three 5-gallon containers will be collected at each sampling location during baseline and all test conditions; the actual sample volume may

change based on NETL requirements to be outlined in a forthcoming byproducts sampling plan.

Task 6 Program Management and Reporting. Overall project management will be conducted under this task throughout the duration of the project. To disseminate the progress and results of the project, reporting and technology transfer activities will be conducted, including preparing data for COR briefings, DOE contractor review meetings and technical meetings.

Subtask 6.1 Reporting. Periodic, topical, and final reports will be prepared and submitted to DOE as part of this task in accordance with the "Federal Assistance Reporting Checklist" and the instructions accompanying the list regarding frequency, form and format.

D. Deliverables

The initial project plan, QA/QC plan, and health and safety plan will be finalized by the project team and submitted to the NETL COR for review and acceptance. On a quarterly basis, Federal Assistance Program/Project Status Reports will be prepared and submitted to DOE/NETL. Technical progress reports will be generated on quarterly basis to summarize the results of the sorbent injection test program. These reports will include a summary of all data obtained, problems encountered, and plans for the immediate future. PowerPoint updates will be submitted to the COR on a quarterly basis, based on templates generated by the COR. Topical reports will be prepared, as required. A final report will be issued at the end of the program summarizing the test results at Units 1 and 2 and the final economic analysis. Environmental reports will be prepared, including a Hazardous Substance Plan once the award is made and Hazardous Waste Report at the

end of the program. A property report consisting of a Report of Termination or Completion Inventory will be submitted at the end of the program.

E. Briefings/Technical Presentations

Detailed briefings shall be given to the COR in order to explain the plans, progress, and results of the project. A technical paper shall be given at the DOE/NETL Annual Contractor's Review Meeting.